

In the Claims:

This listing of claims will replace all prior versions, and listings of claims in the application. Please cancel claims 1-81 without prejudice to or disclaimer of the subject matter therein. Please add new claims 82-101. No new matter has been added.

Listing of Claims:

Claims 1-81 (Cancelled)

82. (New) An apparatus, comprising:

a manipulandum moveable in at least two degrees of freedom;

a linkage coupled to the manipulandum, the linkage including a plurality of elements, at least a subset of elements from the plurality of elements being flexibly coupled to each other and moveable in at least one of said two rotary degrees of freedom; and

at least one sensor configured to detect at least one of a position and a movement of the manipulandum in the at least two degrees of freedom and output a sensor signal based on the detected at least one of the position and the movement.

83. (New) The apparatus of claim 82, further comprising an actuator coupled to the linkage, the actuator configured to output via the subset of elements a feedback force along at least one of the at least two degrees of freedom.

84. (New) The apparatus of claim 82, wherein the linkage includes:

a ground member configured to be coupled to a ground surface;

a first extension member and a second extension member, the first extension member and the second extension member being coupled to the ground member; and

a first central member and a second central member, the first central member having an end coupled to the first extension member, the second central member having an end coupled to the second extension member, the first central member and the second central member being coupled to each other at ends opposite the ends coupled to the first extension member and the second extension member.

85. (New) The apparatus of claim 82, wherein the linkage includes:

a ground member configured to be coupled to a ground surface;

a first extension member and a second extension member, the first extension member and the second extension member being coupled to the ground member; and

a first central member and a second central member, the first central member having an end flexibly coupled to the first extension member, the second central member having an end flexibly coupled to the second extension member, the first central member and the second central member being coupled to each other at ends opposite the ends coupled to the first extension member and the second extension member.

86. (New) The apparatus of claim 82, wherein the linkage includes:

a ground member configured to be coupled to a ground surface;

a first extension member and a second extension member, the first extension member and the second extension member being coupled to the ground member; and

a first central member and a second central member, the first central member having a first end coupled to the first extension member, the second central member having a first end coupled to the second extension member, a second end of the first central member and a second end of the second central member being coupled to each other,

the ground member being rotatably coupled to the first extension member and the second extension member by bearings, the bearings configured to permit rotation of the first extension member and the second extension member.

87. (New) The apparatus of claim 82, wherein at least one element from the subset of elements is narrower in a dimension in which that element is configured to flex, and is wider in other dimensions in which that element is configured to be substantially inflexible.

88. (New) The apparatus of claim 82, further comprising:
a first actuator coupled to the linkage, the actuator configured to output via the subset of elements a feedback force in at least one of the at least two degrees of freedom based on the sensor signal; and

a second actuator coupled to the ground member, the second actuator being configured to apply a feedback force in at least one of the at least two degrees of freedom based on the sensor signal, the feedback force associated with the second actuator being different from the feedback force associated with the first actuator.

89. (New) The apparatus of claim 82, further comprising an actuator coupled to the linkage, the actuator configured to output via the subset of elements a feedback force along at least one of the at least two degrees of freedom, the actuator including a voice coil actuator configured to impart the feedback force on the manipulandum.

90. (New) An apparatus, comprising:

a manipulandum moveable in at least two rotary degrees of freedom about axes of rotation with respect to a reference;

a first member coupled to the manipulandum;

a second member flexibly coupled to the first member; and

a third member flexibly coupled to the first member, the first member, the second member and the third member.

91. (New) The apparatus of claim 90, wherein the first member and the second member are coupled to an intermediate member that is coupled to the manipulandum.

92. (New) The apparatus of claim 90, wherein at least one of the first member, the second member and the third member has a first dimension about which the at least one member is configured to flex, and has a second dimension about which the at least one member is configured to be substantially inflexible.

93. (New) An apparatus, comprising:

a manipulandum movable in a first degree of freedom about an axis of rotation and a second degree of freedom about an axis of rotation different from the axis of rotation for the first degree of freedom;

a linkage coupled to the manipulandum and including two members rotatably coupled to each other;

an actuator configured to generate a feedback force in the first degree of freedom to the linkage; and

a friction drive mechanism coupled to the actuator and the linkage, the actuator being configured such that the feedback force is imparted to the linkage via frictional contact of a plurality of members of the friction drive mechanism, the plurality of members including a drive roller and a moveable member having a rigid portion in frictional contact with the drive roller.

94. (New) The apparatus of claim 93, wherein the moveable member includes a rotatable drum, the rigid portion of the moveable member includes a drive bar, the drive bar and the drive roller coupled to the actuator, the drive roller configured to frictionally engage the drive bar to rotate the rotatable drum and impart the feedback force to the manipulandum in the first degree of freedom.

95. (New) The apparatus of claim 94, further comprising a passive roller, the drive bar having a first side coupled to the drive roller and a second side opposite the first side, the passive roller configured to frictionally engage the drive bar on the second side.

96. (New) The apparatus of claim 93, wherein the manipulandum includes one of a simulated surgical tool, a stylus, and a joystick.

97. (New) The apparatus of claim 93, the actuator being a first actuator, the apparatus further comprising:

a second actuator coupled to the linkage and configured to generate a feedback force in the second degree of freedom, the first actuator and the second actuator being coupled to a ground member of the linkage; and

a second friction drive mechanism coupled to the second actuator and the linkage, the second friction drive mechanism configured to impart the feedback force from the second actuator to the manipulandum in the second degree of freedom.

98. (New) The apparatus of claim 93, wherein the linkage includes a closed-loop five member linkage, each member of the five members being rotatably coupled to at least two other members of the five members.

99. (New) A device, comprising:
a manipulandum moveable in at least one degree of freedom;
an actuator coupled to the manipulandum;
a sensor configured to detect motion of the manipulandum in the at least one degree of freedom and provide a sensor signal; and

a friction drive mechanism coupled between the actuator and the manipulandum, the actuator configured such that a feedback force is imparted to the manipulandum via frictional contact of a plurality of members of the friction drive mechanism, the feedback force being based at least in part on the sensor signal.

100. (New) The device of claim 99, wherein the plurality of members of the friction drive mechanism include a drive roller and a drive bar in direct frictional contact with the drive

roller, the drive roller being coupled to and driven by the actuator, the feedback force being applied to the drive bar by the actuator through the frictional contact.

101. (New) The device of claim 99, wherein the manipulandum includes one of a simulated surgical tool, a stylus, and a joystick.